

WHAT IS CLAIMED IS:

1 1. A robotic surgery system for performing a surgical procedure on a
2 patient lying on an operating table within an operating room, the room having a ceiling-
3 height support structure extending generally above the table and personnel-usable space
4 adjacent the table, the system comprising:
5 a mounting base;
6 a surgical end effector; and
7 a linkage movably supporting the end effector relative to the mounting base,
8 the linkage comprising:
9 a plurality of driven joints coupled to a servomechanism for moving the end
10 effector so as to manipulate tissues;
11 at least one pre-configuration link; and
12 a plurality of releasably fixable joints coupled to the at least one pre-
13 configuration link for pre-configuring the linkage, the releasably fixable joints
14 accommodating vertical movement of the end effector relative to the mounting base; and
15 the mounting base is mountable upon the ceiling-height support structure so as
16 to permit the linkage to be pre-configured to extend generally downward from the mounting
17 base to support the end effector adjacent the patient.

1 2. The robotic surgery system of claim 1, wherein the linkage is pre-
2 configurable to support the end effector adjacent the patient so that the at least one pre-
3 configuration link and the plurality of releasably fixable joints of the pre-configured linkage
4 are disposed generally clear of the personnel-usable space adjacent the operating table.

1 3. The robotic surgery system of claim 1, further comprising:
2 a brake system coupled to the fixable joints, the brake system releasably
3 inhibiting inadvertent articulation of the fixable joints previously configured in an at least
4 substantially fixed configuration;
5 wherein the brake system is biased toward the fixed configuration and the
6 brake system comprises a brake release actuator for releasing the fixable joints to a manually
7 repositionable configuration in which the fixable joints can be manually articulated.

1 4. The robotic surgery system of claim 3, wherein the fixable joints in the
2 repositionable configuration articulate to accommodate manual translation of the end effector
3 in three dimensions.

1 5. The robotic surgery system of claim 4, wherein the fixable joints in the
2 repositionable configuration further articulate to accommodate manual rotation of the end
3 effector about least one axis relative to the base.

1 6. The robotic surgery system of claim 5, wherein the linkage comprises a
2 plurality of fixable links and a plurality of rigid driven links, the fixable links coupled
3 together by the fixable joints, the driven links coupled together by the driven joints, wherein
4 the fixable links are supported by the mounting base and the driven links are supported by the
5 fixable links.

1 7. The robotic surgery system of claim 6, wherein the fixable links
2 include at least one balanced, fixable, jointed-parallelogram linkage structure extending
3 between a pair of adjacent fixable rotational joints, the jointed-parallelogram structure
4 accommodating motion in a generally vertical direction, and the adjacent rotational joints
5 accommodating pivotal motion about vertical axes.

1 8. The robotic surgery system of claim 1, wherein the robotic linkage
2 includes a rigid shaft coupled to the end effector, and at least one of the robotic linkage, the
3 servomechanism and a combination of the linkage and servomechanism acts to constrain the
4 shaft to rotation about a pivot point along the shaft, and wherein actuation of the fixable
5 joints moves the pivot point and the shaft

1 9. The robotic surgery system of claim 1, the linkage further comprising a
2 joint sensor system coupling the fixable joints to the servomechanism, the sensor system
3 generating joint configuration signals, wherein the servomechanism includes a computer and
4 wherein the joint sensor system transmits the joint configuration signals to the computer.

1 10. The robotic surgery system of claim 9, wherein the computer
2 calculates a coordinate system transformation between a reference coordinate system affixed
3 relative to the base and the end effector using the joint configuration signals

1 11. The robotic surgery system of claim 10, further comprising a plurality
2 of robotic linkages, each linkage including a plurality of joints coupled to the sensor system
3 and supporting an associated end effector, wherein the computer calculates coordinate system

4 transformations between the reference coordinate system and each of the end effectors using
5 the joint configuration signals.

1 12. The robotic surgery system of claim 11, wherein a joint signal of at
2 least one of the sensors of the sensor system varies with an absolute position of the joint.

1 13. A support apparatus for supporting a first robotic surgical manipulator
2 relative to a second robotic surgical manipulator, each surgical manipulator coupled to a
3 servomechanism so as to robotically manipulate tissues of a patient body with a surgical end
4 effector while the patient lies on an operating table within an operating room, the room
5 having a ceiling-height support structure extending generally above the table and personnel-
6 usable space adjacent the table, the support apparatus comprising:

7 a mounting base;

8 a first support linkage mounted to the base and movably supporting the first
9 manipulator relative to the base, the first support linkage accommodating vertical movement
10 of the first manipulator relative to the mounting base;

11 the base is mountable upon the ceiling-height support structure so as to permit
12 the first support linkage to be pre-configured to extend generally downward from the base to
13 support the first manipulator adjacent the patient;

14 a second support linkage supporting the second manipulator relative to the
15 base; and

16 a sensor system coupling the first and second support linkages to the
17 servomechanism, the sensor system transmitting position signals to the servomechanism, the
18 servomechanism calculating at least one of a position and an orientation of the first
19 manipulator relative to the second manipulator using the signals.

1 14. The support apparatus of claim 13, wherein the first support linkage is
2 pre-configurable to support the first manipulator adjacent the patient so that the pre-
3 configured linkage is disposed generally clear of the personnel-usable space adjacent the
4 operating table.

1 15. The support apparatus of claim 13, wherein the first support linkage
2 comprises:

3 an articulated linkage having a plurality of releasably fixable joints coupling
4 the base to the first manipulator so as to allow manual movement of the first manipulator
5 relative to the base for pre-configuring the linkage, and
6 a brake system releasably inhibiting inadvertent movement of the joints,
7 wherein the sensor system is coupled to the joints so that the position signals comprise joint
8 configuration signals of the joints.

1 16. The support apparatus of claim 15, wherein the brake system is biased
2 toward the fixed configuration and the brake system comprises a brake release actuator for
3 releasing the fixable joints to a manually repositionable configuration in which the fixable
4 joints can be manually articulated.

1 17. The support apparatus of claim 16, wherein the brake system can
2 release the joints upon actuation of a single actuator.

1 18. The support apparatus of claim 17, wherein the joints articulate to
2 accommodate manual translation of the manipulator and handle in three dimensions.

1 19. The support apparatus of claim 18, wherein the joints further articulate
2 to accommodate manual rotation of an end effector coupled to the first manipulator about at
3 least one axis relative to the base.

1 20. The support apparatus of claim 15, wherein the first support linkage is
2 balanced about the joints

1 21. The support apparatus of claim 15, wherein the first support linkage
2 includes at least one balanced, fixable, jointed-parallelogram linkage structure extending
3 between a pair of adjacent fixable rotational joints, the jointed-parallelogram structure
4 accommodating motion in a generally vertical direction, and the adjacent rotational joints
5 accommodating pivotal motion about vertical axes.

1 22. A method for preparing for robotic surgery on a patient lying on an
2 operating table within an operating room, the room having a ceiling-height support structure
3 extending generally above the table and personnel-usable space adjacent the table, the
4 surgery employing a surgical manipulator having servo-mechanically driven joints, the
5 method comprising:

6 maintaining driven joints of the surgical manipulator sufficiently near mid
7 points of travel of the joints so as to inhibit interference with a limit of travel of the
8 manipulator within an intended worksite;

9 pre-positioning the manipulator while maintaining the driven joints near the
10 mid points by manually articulating a linkage coupled to the manipulator and to a mounting
11 base, the linkage accommodating vertical movement of the manipulator relative to the
12 mounting base, and the base being mounted upon the ceiling-height support structure so that
13 the pre-positioned linkage extends generally downward from the base to support the
14 manipulator adjacent the patient; and

15 restraining the positioned manipulator with a brake system so as to prevent
16 articulation of the linkage.

1 23. The method of claim 22, wherein the pre-positioning step comprises
2 pre-positioning the linkage so that the pre-positioned linkage is disposed generally clear of
3 the personnel-usable space adjacent the operating table.

1 24. The method of claim 22, wherein the pre-positioning step comprises
2 orienting a manipulator shaft towards an internal access site, the manipulator being adapted to
3 pivot the shaft about the access site so as to manipulate tissues endoscopically.

1 25. A robotic surgery system for performing a surgical procedure on a
2 patient lying on an operating table within an operating room, the room having a support
3 structure extending generally below the table and personnel-usable space adjacent the table,
4 the system comprising:

5 a base;

6 a surgical end effector; and

7 a linkage movably supporting the end effector relative to the base, the linkage
8 comprising:

9 a plurality of driven joints coupled to a servomechanism for moving the end
10 effector so as to manipulate tissues;

11 at least one pre-configuration link; and

12 a plurality of releasably fixable joints coupled to the at least one pre-
13 configuration link for pre-configuring the linkage, the releasably fixable joints
14 accommodating vertical movement of the end effector relative to the base; and

15 the base is mountable upon the support structure so as to permit the linkage to
16 be pre-configured to extend generally upward from the base to support the end effector
17 adjacent the patient.

1 26. The robotic surgery system of claim 25, wherein the linkage is pre-
2 configurable to support the end effector adjacent the patient so that the at least one pre-
3 configuration link and the plurality of releasably fixable joints of the pre-configured linkage
4 are disposed generally clear of the personnel-usable space adjacent the operating table.

1 27. The robotic surgery system of claim 25, further comprising:
2 a brake system coupled to the fixable joints, the brake system releasably
3 inhibiting inadvertent articulation of the fixable joints previously configured in an at least
4 substantially fixed configuration;

5 wherein the brake system is biased toward the fixed configuration and the
6 brake system comprises a brake release actuator for releasing the fixable joints to a manually
7 repositionable configuration in which the fixable joints can be manually articulated.

1 28. The robotic surgery system of claim 27, wherein the fixable joints in
2 the repositionable configuration articulate to accommodate manual translation of the end
3 effector in three dimensions.

1 29. The robotic surgery system of claim 28, wherein the fixable joints in
2 the repositionable configuration further articulate to accommodate manual rotation of the end
3 effector about least one axis relative to the base.

1 30. The robotic surgery system of claim 29, wherein the linkage comprises
2 a plurality of fixable links and a plurality of rigid driven links, the fixable links coupled
3 together by the fixable joints, the driven links coupled together by the driven joints, wherein
4 the fixable links are supported by the mounting base and the driven links are supported by the
5 fixable links.

1 31. The robotic surgery system of claim 30, wherein the fixable links
2 include at least one balanced, fixable, jointed-parallelogram linkage structure extending
3 between a pair of adjacent fixable rotational joints, the jointed-parallelogram structure
4 accommodating motion in a generally vertical direction, and the adjacent rotational joints
5 accommodating pivotal motion about vertical axes.

1 32. The robotic surgery system of claim 25, wherein the robotic linkage
2 includes a rigid shaft coupled to the end effector, and at least one of the robotic linkage, the
3 servomechanism and a combination of the linkage and servomechanism acts to constrain the
4 shaft to rotation about a pivot point along the shaft, and wherein actuation of the fixable
5 joints moves the pivot point and the shaft.

1 33. The robotic surgery system of claim 25, the linkage further comprising
2 a joint sensor system coupling the fixable joints to the servomechanism, the sensor system
3 generating joint configuration signals, wherein the servomechanism includes a computer and
4 wherein the joint sensor system transmits the joint configuration signals to the computer.

1 34. The robotic surgery system of claim 33, wherein the computer
2 calculates a coordinate system transformation between a reference coordinate system affixed
3 relative to the base and the end effector using the joint configuration signals

1 35. The robotic surgery system of claim 34, further comprising a plurality
2 of robotic linkages, each linkage including a plurality of joints coupled to the sensor system
3 and supporting an associated end effector, wherein the computer calculates coordinate system
4 transformations between the reference coordinate system and each of the end effectors using
5 the joint configuration signals.

1 36. The robotic surgery system of claim 35, wherein a joint signal of at
2 least one of the sensors of the sensor system varies with an absolute position of the joint.

1 37. A support apparatus for supporting a first robotic surgical manipulator
2 relative to a second robotic surgical manipulator, each surgical manipulator coupled to a
3 servomechanism so as to robotically manipulate tissues of a patient body with a surgical end
4 effector while the patient lies on an operating table within an operating room, the room
5 having a support structure extending generally below the table and personnel-usable space
6 adjacent the table, the support apparatus comprising:

7 a base;

8 a first support linkage mounted to the base and movably supporting the first
9 manipulator relative to the base, the first support linkage accommodating vertical movement
10 of the first manipulator relative to the base;

11 the base is mountable upon the support structure so as to permit the first
12 support linkage to be pre-configured to extend generally upward from the base to support the
13 first manipulator adjacent the patient;

14 a second support linkage supporting the second manipulator relative to the
15 base; and

16 a sensor system coupling the first and second support linkages to the
17 servomechanism, the sensor system transmitting position signals to the servomechanism, the
18 servomechanism calculating at least one of a position and an orientation of the first
19 manipulator relative to the second manipulator using the signals.

1 38. The support apparatus of claim 37, wherein the first support linkage is
2 pre-configurable to support the first manipulator adjacent the patient so that the pre-
3 configured linkage is disposed generally clear of the personnel-usuable space adjacent the
4 operating table.

1 39. The support apparatus of claim 37, wherein the first support linkage
2 comprises:

3 an articulated linkage having a plurality of releasably fixable joints coupling
4 the base to the first manipulator so as to allow manual movement of the first manipulator
5 relative to the base for pre-configuring the linkage, and

6 a brake system releasably inhibiting inadvertent movement of the joints,
7 wherein the sensor system is coupled to the joints so that the position signals comprise joint
8 configuration signals of the joints.

1 40. The support apparatus of claim 39, wherein the brake system is biased
2 toward the fixed configuration and the brake system comprises a brake release actuator for
3 releasing the fixable joints to a manually repositionable configuration in which the fixable
4 joints can be manually articulated.

1 41. The support apparatus of claim 40, wherein the brake system can
2 release the joints upon actuation of a single actuator.

1 42. The support apparatus of claim 41, wherein the joints articulate to
2 accommodate manual translation of the manipulator and handle in three dimensions.

1 43. The support apparatus of claim 42, wherein the joints further articulate
2 to accommodate manual rotation of an end effector coupled to the first manipulator about at
3 least one axis relative to the base.

1 44. The support apparatus of claim 39, wherein the first support linkage is
2 balanced about the joints

1 45. The support apparatus of claim 39, wherein the first support linkage
2 includes at least one balanced, fixable, jointed-parallelogram linkage structure extending
3 between a pair of adjacent fixable rotational joints, the jointed-parallelogram structure
4 accommodating motion in a generally vertical direction, and the adjacent rotational joints
5 accommodating pivotal motion about vertical axes.

1 46. A method for preparing for robotic surgery on a patient lying on an
2 operating table within an operating room, the room having a support structure extending
3 generally below the table and personnel-usuable space adjacent the table, the surgery
4 employing a surgical manipulator having servo-mechanically driven joints, the method
5 comprising:

6 maintaining driven joints of the surgical manipulator sufficiently near mid
7 points of travel of the joints so as to inhibit interference with a limit of travel of the
8 manipulator within an intended worksite;

9 pre-positioning the manipulator while maintaining the driven joints near the
10 mid points by manually articulating a linkage coupled to the manipulator and to a mounting
11 base, the linkage accommodating vertical movement of the manipulator relative to the
12 mounting base, and the base being mounted upon the support structure so that the pre-
13 positioned linkage extends generally upward from the base to support the manipulator
14 adjacent the patient; and

15 restricting the positioned manipulator with a brake system so as to prevent
16 articulation of the linkage.

1 47. A robotic surgery system for performing a surgical procedure on a
2 patient lying on an operating table within an operating room, the room having personnel-
3 usable space adjacent the table, having a ceiling-height support structure extending generally
4 above the table and having a below-table support structure extending generally below the
5 table, the system comprising:

6 at least one ceiling-height-mounted robotic arm assembly comprising:
7 a first base;
8 a first surgical manipulator coupled to an first end effector;
9 a first linkage including a plurality of releasably fixable joints for pre-
10 configuring the first linkage, the releasably fixable joints accommodating vertical movement
11 of the first manipulator relative to the first base; and
12 the first base is mountable upon the ceiling-height support structure so as to
13 permit the first linkage to be pre-configured to extend generally downward from the first base
14 to support the first end effector adjacent the patient; and
15 at least one below-table-mounted robotic arm assembly comprising:
16 a second base;
17 a second surgical manipulator coupled to an second end effector;
18 a second linkage including a plurality of releasably fixable joints for pre-
19 configuring the second linkage, the releasably fixable joints accommodating vertical
20 movement of the second manipulator relative to the second base; and
21 the second base is mountable upon the below table support structure so as to
22 permit the second linkage to be pre-configured to extend generally upward from the second
23 base to support the second end effector adjacent the patient.

1 48. The robotic surgery system of claim 47, wherein the first and second
2 linkages are pre-configurable to support the first and second end effectors adjacent the patient
3 so that the at least one ceiling-height-mounted robotic arm assembly and the at least one
4 below-table-mounted robotic arm assembly are disposed generally clear of the personnel-
5 usable space adjacent the operating table.

1 49. The robotic surgery system of claim 48, wherein at least one of the
2 ceiling-height-mounted robotic arm assembly and the below-table-mounted robotic arm
3 assembly further comprises:

4 a brake system coupled to the fixable joints, the brake system releasably
5 inhibiting inadvertent articulation of the fixable joints previously configured in an at least
6 substantially fixed configuration;

7 wherein the brake system is biased toward the fixed configuration and the
8 brake system comprises a brake release actuator for releasing the fixable joints to a manually
9 repositionable configuration in which the fixable joints can be manually articulated.

1 50. The robotic surgery system of claim 49, wherein the at least one
2 ceiling-height-mounted robotic arm assembly and the at least one below-table-mounted
3 robotic arm assembly include:

4 at least a total of four robotic arm assemblies operatively controllable by a
5 single operator, wherein at least one of the manipulator-supported end effectors is an
6 endoscopic image capture device.

1 51. The robotic surgery system of claim 49, wherein the at least one
2 ceiling-height-mounted robotic arm assembly and the at least one below-table-mounted
3 robotic arm assembly include:

4 at least four robotic arm assemblies, wherein at least one of the manipulator-
5 supported end effectors being an endoscopic image capture device, at least one of the robotic
6 arm assemblies being simultaneously operatively controllable by a different operator than at
least one of the other robotic arm assemblies.

1 52. The robotic surgery system of claim 51, wherein the robotic arm
2 assemblies include:

3 at least three robotic arm assemblies which are operatively controllable by a
4 first operator; and

5 at least three robotic arm assemblies which are simultaneously operatively
6 controllable by a second operator.